

TABLE 2.—Vapor pressures at pyrheliometric stations on days when solar radiation intensities were measured.

Washington, D. C.			Madison, Wis.			Lincoln, Nebr.			Santa Fe, N. Mex.		
Dates.	S.a.m.	S.p.m.	Dates.	S.a.m.	S.p.m.	Dates.	S.a.m.	S.p.m.	Dates.	S.a.m.	S.p.m.
1918.	mm.	mm.	1918.	mm.	mm.	1918.	mm.	mm.	1918.	mm.	mm.
Mar. 2	3.15	4.57	Mar. 1	1.96	3.15	Mar. 1	2.26	4.37	Mar. 1	2.36	4.17
4	3.39	4.75	2	3.45	3.15	7	2.26	2.87	4	3.45	3.81
7	6.02	3.00	7	2.26	3.03	16	2.87	3.53	9	3.15	3.15
8	3.45	3.15	15	1.32	2.26	19	2.49	3.63	14	2.26	2.16
11	1.78	3.15	16	2.62	4.17	21	6.50	3.81	15	2.49	2.26
16	2.49	3.45	19	3.45	5.79	24	3.03	3.81	16	2.26	2.16
18	3.81	5.36	22	3.15	3.30	25	3.15	3.63	18	2.62	1.96
23	3.63	3.99	26	3.30	3.30	27	3.81	5.79	22	3.00	4.95
25	6.02	1.64	27	3.00	2.74				23	3.81	4.37
26	2.62	2.26	28	3.15	4.57				25	3.45	3.99
27	2.49	3.15							30	4.37	3.15
28	3.45	3.81									
29	3.63	4.37									

TABLE 3.—Daily totals and departures of solar and sky radiation during March, 1918.

[Gram calories per square centimeter of horizontal surface.]

Day of month.	Daily totals.			Departures from normal.			Excess or deficiency since first of month.		
	Wash- ington.	Mad- ison.	Lin- coln.	Wash- ington.	Mad- ison.	Lin- coln.	Wash- ington.	Mad- ison.	Lin- coln.
	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
1.....	72	413	464	-223	145	113	-223	115	113
2.....	428	307	412	129	95	58	-94	340	171
3.....	467	414	131	165	107	-227	71	317	-56
4.....	185	179	365	-121	-132	4	-50	215	-32
5.....	365	139	114	56	-176	-251	6	39	-303
6.....	251	125	294	-61	-193	-74	-55	-154	-377
7.....	368	408	435	53	80	65	-2	-68	-312
8.....	443	165	310	125	-160	-65	123	-228	-375
9.....	76	16	205	-245	-312	-170	-122	-540	-545
10.....	293	455	468	-31	123	90	-153	-417	-455
11.....	457	331	430	130	-1	50	-23	-421	-405
12.....	54	350	430	-246	12	47	-260	-409	-358
13.....	41	35	203	-292	-306	-182	-561	-715	-540
14.....	47	239	256	-289	-105	-132	-850	-820	-672
15.....	419	526	445	-80	179	55	-770	-611	-617
16.....	521	534	502	180	154	109	-590	-457	-508
17.....	370	456	472	26	104	77	-564	-333	-431
18.....	467	419	121	64	-443	-289	-431
19.....	415	472	541	66	114	142	-377	-175	-289
20.....	412	424	371	61	64	-31	-316	-111	-320
Decade departure.....							-163	+306	135
21.....	63	289	492	-291	-74	88	-607	-185	-232
22.....	350	402	499	-6	96	93	-613	-89	-139
23.....	528	505	401	169	137	-7	-44	48	-116
24.....	421	493	494	60	122	84	-384	170	-62
25.....	486	315	528	122	-59	116	-265	111	54
26.....	428	473	508	62	97	94	-200	298	148
27.....	532	551	488	163	173	73	-37	381	221
28.....	454	528	316	83	147	-101	216	528	129
29.....	539	461	301	165	78	-28	211	606	62
30.....	450	493	486	74	108	66	285	714	158
31.....	474	342	469	95	-45	47	380	609	205
Decade departure.....							+696	+780	+575
Excess or deficiency since first of year.	{Gram calories.....						+517	+1,538	-550
	{Per cent.....						+2.3	+6.7	-2.0

A PROMISING CHEMICAL PHOTOMETER FOR PLANT PHYSIOLOGICAL RESEARCH.

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Botanical literature is replete with references regarding the effect of light upon plants from the viewpoint of the physiologist, the anatomist, the histologist, the ecologist and the agriculturist. Numerous methods and instruments have been devised and used, and with some success, for the determination of the intensity or nature, or both, of the insolation of the plant under observation. So far as the writer is aware, all of these methods and

instruments are possessed of objectionable limitations, either in reliability, initial cost, or cost of operation. It seems advisable, therefore, to call attention to a photometer which, at the present stage in its trial, at least indicates its practicability in connection with investigations of the light relations of plants. Allusion is had to the use of oxalic acid and uranium salts as advocated by Dr. Raymond F. Bacon.¹

Through the courtesy of the United States Weather Bureau, and with the kind cooperation of Prof. H. H. Kimball of that bureau, some comparisons have been made of the records obtained by the Callender recording pyrheliometer with the results of exposure of the chemical photometer, with the idea of standardizing the latter.

In testing out the chemical photometer, the writer used uranium acetate and oxalic acid in the proportions of 1 part by weight of the former to 20 of the latter; that is, 5 cubic centimeters of a 1 per cent (0.023 molecular) aqueous solution of the uranium salt to 20 cubic centimeters of a 5 per cent (0.71 molecular) aqueous solution of the acid. (In most of his experiments Dr. Bacon used a proportion of 1 to 10. In the present tests, however, the amount of oxalic acid was increased in order that long exposures might be made.) The solutions were brought together in Florence flasks of 100 cubic centimeters capacity, plugged with loose wads of cotton,² and the flasks so adjusted in holes in a blackened board that the surface of the liquid in each flask was flush with the upper surface of the board, the neck of the flask being inclined to the north so that no shadow would be cast upon the liquid. This method of excluding the light from the sides of the flask was adopted in order that only the horizontal surface of the liquid would be exposed to the sunlight and thereby be more nearly comparable with the horizontally exposed receiving portion of the pyrheliometer. After exposure the oxalic-acid-uranium-acetate mixture was titrated with potassium permanganate (2N solution) in the following manner: The mixture was increased to a convenient volume for titration, either in the original flask or after having been transferred to a beaker, by the addition of distilled water. The volume to be titrated was then heated to 70° C., made strongly acid by the addition of 1:1 sulphuric acid and the potassium permanganate end point determined while the solution was still hot. Though Dr. Bacon states that he removed the uranium salt before titration by the addition of a slight excess of ammonium hydrate, the writer found that aliquots of the same solution gave no differences in the amount of oxalic acid present, whether the uranium was removed or not, and, therefore, did not use the ammonium hydrate. It was found that in cool weather a 10 per cent solution of oxalic acid became supersaturated, when the temperature dropped during the night, to such an extent that the stock bottle contained crystals the following morning when it was desired to make up fresh mixtures for exposure. Because of this fact it was necessary to use double the quantity of a 5 per cent oxalic acid solution.

A series of 13 comparisons of the chemical photometer with the pyrheliometer was run during the months of May and June, 1917. The length of exposure of the solution ranged from 8 to 24 hours, although in most cases the flasks were first exposed after dark in the evening and taken in after dark the next evening,

¹ Bacon, R. F. A solution of oxalic acid and uranium salts as a chemical photometer. Philip Jour. sci., A. Manila, 1910, 5: 281-303.

² The flasks could not be completely closed since Dr. Bacon says: "For all practical purposes the decomposition of oxalic acid under the influence of uranyl salts may be assumed to take place as follows: $\text{H}_2\text{C}_2\text{O}_4 \rightarrow \text{CO}_2 + \text{CO} + \text{H}_2\text{O}$." Some outlet, therefore, was necessary for the escape of the gases generated.—Author.

giving an exposure of a full 24 hours. The ratio,

$$\frac{\text{calories recorded by pyrheliometer}}{\text{grams oxalic acid decomposed}}$$

for each exposure, the mean ratio of all the exposures, and the percentage departure of each from the mean were computed. It was found that, with a mean of 978 for all the exposures, in nine cases the deviation from the mean ranged between 0.2 and 3 per cent on either side, and that of the four other exposures, one was 6 per cent below the mean and three were 5, 7, and 8 per cent above, respectively.

Tests to determine the stability of the oxalic-acid-uranium-salt mixture in the dark, both before and after exposure, were made repeatedly and indicated that no appreciable decomposition of the oxalic acid takes place within three days if the mixture is kept in a dark closet. The effect of the diffuse light of the laboratory was also tested. The results showed that it would be necessary to expose the photometer for several hours in order to effect a measurable decomposition of oxalic acid when the proportions mentioned above are used. The temperature coefficient of the reaction was disregarded, since Dr. Bacon states that for a remarkably wide range of temperatures this factor need not be considered.

One application of the chemical photometer was demonstrated, at least to the satisfaction of the writer, in determining with it the transmission coefficient of a piece of tobacco shade cloth of 12×12 mesh in connection with investigations of the light relations of the tobacco plant. A flask containing the mixture was exposed (from 9.30 a. m. to 2.30 p. m. on March 21, 1917, a cloudless, bright day) to the sunlight which passed through the cloth stretched over the south side and top of a small frame. During the same period a second flask was exposed to uninterrupted sunlight and a third to the light of a portion of the northern sky together with some reflected light from a low white wall opposite the north window in which the last-mentioned exposure was made. At the end of the 5 hours the contents of the three flasks were titrated and the decomposition of oxalic acid (0.229 gram) in the fully insulated mixture was taken as 100 per cent. The decomposition in the shaded flask (0.121 gram) showed that in passing through the cloth the photochemical effect of the light as measured by this reaction had been reduced to 47.2 per cent. The decomposition in the flask exposed to the north light was 0.029 gram, or 12.6 per cent of that which took place during the same time in the flask in direct sunlight. The figure for the transmission of the shade cloth is nearly the same as the coefficient determined by Prof. Kimball³ with the use of the Smithsonian silver-disk pyrheliometer (42.7 per cent at normal incidence) when it is considered that the flask under the cloth was subjected to considerable reflected light from a white wall during the exposure. The same is true of the flask exposed in a north window—that is, the percentage of total light (12.6 per cent) also includes some reflected light from the wall to the north of the flask.

Experiments to determine the reliability of the solutions and the accuracy of titration of the oxalic acid showed, by the use of series of duplicate flasks exposed simultaneously, that there were no differences beyond an experimental error of ±1 per cent. The results of further experiments conducted for the purpose of measuring the intensity of the sunlight on clear days, hour by hour, produced a curve very similar to the records obtained with the pyrheliometer. This was true whether separate

exposures of an hour each were made or aliquots were taken at the end of each hour from a continuously exposed volume of the oxalic-acid-uranium-acetate mixture.

From the tests outlined above, this chemical photometer seems to be affected by light in a degree comparable to the pyrheliometer in spite of the fact that the two instruments doubtless are influenced by different portions of the solar spectrum. Dr. Bacon cites several published articles tending to show that solutions of both uranium salts and oxalic acid produce absorption bands in that region of the spectrum characterized by short wave lengths, and makes the statements: “. . . it may be considered as being fairly well established that the active rays from the sun measured by this solution are in the ultra-violet,” and further “. . . I do not consider that there is any good reason for classifying the sun's rays into infra-red or heat rays, visible rays, and ultra-violet or chemical rays, as there are just as many chemical reactions effected by light corresponding to the visible and even infra-red parts of the spectrum as there are by the ultra-violet portion.” In Bacon's Table V, however, the decomposition in a solution exposed in a quartz beaker was somewhat less than that in a similar solution exposed at the same time in a glass flask. Since the reaction does take place in a glass container, it seems probable that rays other than the ultra-violet, are active upon the solution. This seems even more certain when it is considered that of the total range of ultra-violet light (3,920—1,000 Ångström units) only those over 2,910 Å. in length reach the earth and that none less than 3,000 Å. are capable of passing through glass. It should be stated further that the rays over 3,000 Å. in length are not bactericidal and, hence, are probably the least active chemically of the ultra-violet portion of the spectrum so far as living organisms are concerned.⁴

Granting that the chemical photometer shows the chemical effect of light belonging chiefly to the violet end of the spectrum and that the pyrheliometer records the heating effect of the entire spectrum, with its maximum in the infra-red, it seems, from the comparisons made, that the proportion of the two kinds of rays commonly obtaining in ordinary sunlight is responsible for the apparent agreement of the two methods of measurement in a majority of the tests. The cases of

marked departure of the ratio $\frac{\text{calories}}{\text{grams}}$ from the mean of all the observations are thought to be due in most instances to the occurrence of clouds or haze which affected the intensity of the rays at one end of the spectrum to a greater extent than those at the other end. It may be stated, however, that Professor Kimball thought it advisable to discard some of the comparisons made because of the presence during the exposure of moving cumulus clouds which caused the recording pen of the pyrheliometer to move so rapidly that accurate evaluation of its curve was impossible. Another explanation of apparently discordant results lies in the fact that instruments of the recording pen type are liable to considerable error by lagging, especially when actuated by widely different impulses of short duration occurring in rapid succession, such as the effect of moving clouds just mentioned.

Until the question of the specificity of the physiological effect upon plants of light rays of different wave lengths is settled to the satisfaction of plant physiologists, it seems to the writer that a means of light measurement in

³ See Kimball, H. H.—The shading effect of wire insect cages, MONTHLY WEATHER REVIEW, September, 1916, 44: 501-506, for a description of his method of determining shading effect.

⁴ Ayers, H. S. & Johnson, W. T. Destruction of bacteria in milk by ultra-violet light. Centbl. Bakt. (etc.) Abt. 2: Bd. 40; 1914, No. 1/8 pp. 109-131.

general by a chemical method is greatly to be desired. The spectrum of chlorophyll solution shows definite absorption bands in the red and orange and almost general absorption in the blue, indigo, and violet with smaller bands interspersed in other portions. The projection of the solar spectrum for some hours upon a leaf has demonstrated that photosynthesis takes place most prominently in the region of the red and to some extent at other points, though few acceptable results indicating the effect of light of various wave lengths upon other life processes of the plant have been stated.⁵ As far as light is concerned physiological investigations deal, in the main, with that factor in its totality, its effect upon plants being generally regarded as photochemical; hence, the feasibility of the chemical method of measurement herein described, should future investigations confirm its seeming usefulness.

Some of the probable advantages of the method are the ease and low cost with which it may be operated, the avoidance of complicated, costly and frequently unreliable mechanisms, and the reduction of error due to the personal factor in observation, so prominent in the photographic paper method. The chief values of the chemical photometer, however, if its reliability is established, will lie in the facility with which several exposures may be made simultaneously under various degrees of illumination and the fact that the solution gives an automatic integration for the time period of exposure. The automatic exposure of vessels containing light sensitive solutions by the use of clocks has been accomplished by Stone⁶ and a similar arrangement may be advantageous in connection with the one just described. Though plans are made for further work with the oxalic-acid-uranium-salt photometer during the coming growing season, it is hoped that it will be carefully investigated in its application to problems in plant physiology, especially with reference to the correlation of its properties with the various life processes, since such research, though attractive, lies without the province of the writer in his present field of activity.

FURTHER STUDY OF HALOS IN RELATION TO WEATHER.

BY HOWARD H. MARTIN, Observer.

[Dated: Weather Bureau, Columbus, Ohio, March 4, 1918.]

Since 1907 several papers have been prepared on the subject, based on data from isolated stations, and it is the desire of the writer to present herewith, in conjunction with the results obtained at Columbus, Ohio, the collected results of all observations over the United States and to show the possible relation between these results and latitude, longitude, and the average cyclonic tracks.

Blue Hill, Mass. Blue Hill Observatory.

Lat., 42° 21' N.; Long., 71° 4' W. (approximate).

Number of observations, 569, of which 467 were solar and 102 were lunar. Month of greatest frequency: solar halos, average 5.9 in March; lunar halos, average, 2.7 in January. Month of least frequency, solar, average 2.3 in October; lunar, 0.4 in July.

Wauseon, Ohio. Thomas Mikscl, observer.

Lat., 40° N.; Long., 84° W.

Length of record, 1873-1912, inclusive. Total number of halos observed, 2,918, of which 2,219 were solar and 699 were lunar. Month of greatest frequency, April, average 9.2; least, August, average 3.2.

⁵ Richter, A. (in Rev. Gen. de Bot., 1902, p. 212) indicates that the amount of photosynthesis in a leaf subjected to monochromatic light, is a function of the heat energy of that light and independent of its wave-length. Recent articles published by Dr. S. O. Mast in the Journal of Experimental Zoology, deal with the stimulating effect of different spectral colors on lower organisms. The bactericidal action of ultra-violet rays, which must be a function of wave length rather than heat, is well established (Ayers, see footnote 4).

⁶ Stone, G. E. Relation of light to greenhouse culture. Mass. Agri. Expt. Sta. Bull. 144, July, 1913. (Though the results of measurements of light by a photochemical method are stated, the details of the method are not given.)

Fort Worth, Tex. Weather Bureau.

Lat., 32° 43' N.; Long., 97° 15' W.

Length of record, 1910-1915, inclusive. Total number observed 170, of which 86 were solar and 84 were lunar. Month of greatest frequency, January, average 4.0; month of least frequency, September, 0.3.

York, N. Y. Milroy N. Stewart, observer.

Lat., 42° 52' N.; Long., 77° 53' W.

Total number of halos observed 372, of which 317 were solar and 55 lunar. Month of greatest frequency, March, average 3.4; least, June, average 2.1.

Lake Montebello, Md. Martin L. Dobler, observer.

Approximate lat., 39° N.; Long., 76° W.

Total number of 17 observed from November 5, 1905 to December 26, 1906, of which number 9 were solar and 8 lunar.

Columbia, Mo. Weather Bureau.

Lat., 38° 57' N.; Long., 92° 20' W.

The period of observation was approximately two years, during which time 40 halos were observed, of which number 37 were solar and 3 were lunar. The month of greatest frequency was January, least, July and August.

Columbus, Ohio. Weather Bureau.

Lat., 39° 58' N.; Long., 83° 0' W.

Period of observations extends from January 1, 1906 to December 31, 1917, during which time 185 were observed, of which 83 were solar and 102 lunar. Month of greatest frequency, April, 2.4; least, August, 0.2.

The record at Columbus, Ohio, in point of numbers observed, is not as complete, apparently, as it might be, but this is largely due to the generally smoky condition of the atmosphere. In Table 1, showing the general relation to precipitation of halos at this station, no attempt is made to discriminate between the solar and the lunar, sparsity of observations prohibiting. A striking similarity may be noted in the record at this station and the record of Wauseon, Ohio, of the months of greatest and least frequency. During the 12 years record at Columbus, but one halo was observed during the month of August.

TABLE 1.—Relation existing between halos and subsequent precipitation, at Columbus, Ohio, 1906-1917, inclusive.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.
Number considered.....	16	20	24	35	18	7	4	1	5	12	17	18	*181
Per cent followed by precipitation—													
In 18 hours.....	50	25	46	63	77	28	50	100	60	42	53	50	54
In 24 hours.....	69	49	58	74	77	43	75	100	59	59	60	67	65
In 36 hours.....	81	60	65	80	83	57	75	100	100	67	65	72	75
In 48 hours.....	94	65	75	88	89	71	100	100	100	75	82	88	86
Not followed within 60 hours.....	6	30	17	11	11	14	0	0	0	17	12	6	8
Average interval between halo and precipitation.....	23.7	44.4	33.4	24.6	17.2	40.3	39.5	11.4	16.9	28.2	23.9	24.3	26.2
Average duration of halo.....	1.9	2.4	1.7	1.6	1.4	1.2	2.5	2.5	1.6	1.3	1.6	1.5	1.8

* Four halos not considered because of incomplete data.

Table 2 shows all stations arranged according to latitude and longitude, and presents the relative value of the halo as a rain forecast for the several localities. There are indications of a possible maximum percentage of verifications in the higher latitudes, increasing as the longitude decreases.